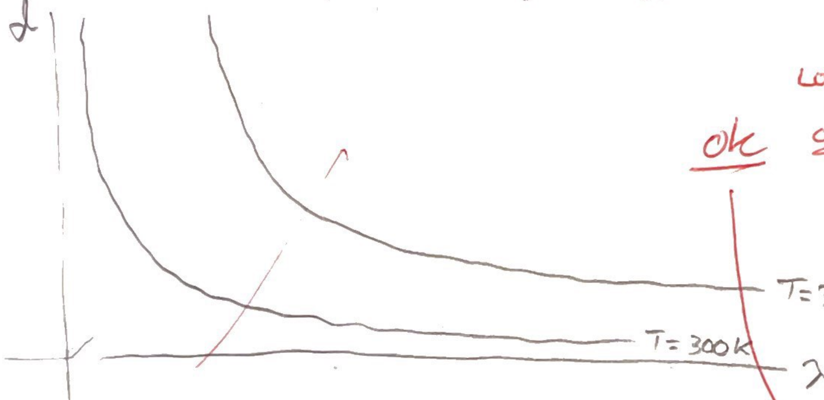
NAME: Taylor Larrechea **Physics 231, Exam 1**

Directions: Please read everything carefully and ask for clarification if need be. This exam is closed-book/closed-note, but you may have a 5X7 notecard. Values for constants will be given. Write/draw answers for pt. 1 on the exam sheet, work and answers for pt. 2 neatly labeled on numbered clean sheets, name on each page.

Part I: Short answer/conceptual questions or quick calculations (5pts each)

1.) Sketch the intensity vs. wavelength curves for two blackbody radiators, one at *T=300* K and one at *T=3000* K on the same axes. ("sketch" means qualitatively, no calculation needed.)



ok

LOGIC IS CORRECT

$\lambda_{max} = \frac{2.898 \times 10^{-3}\ m \cdot K}{T}$

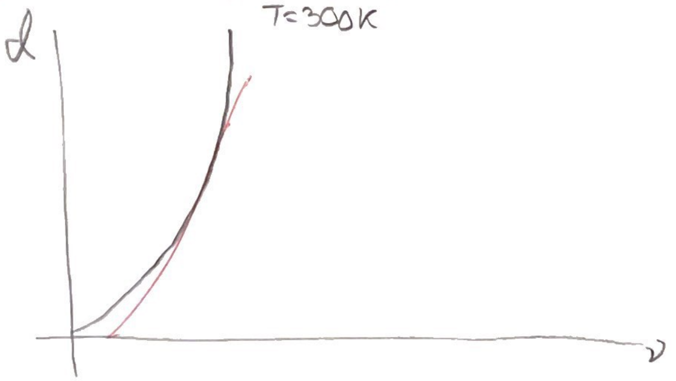
Bigger T, Smaller λ_{max}

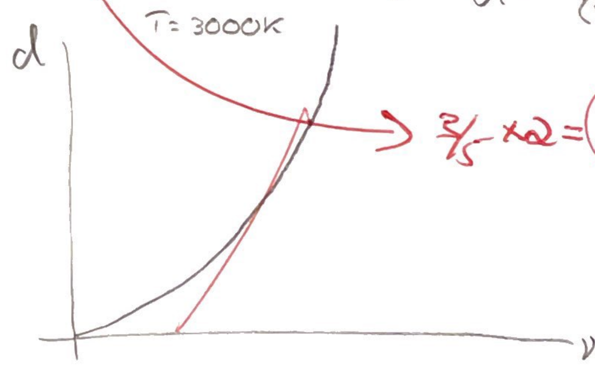
$\mathcal{I}(\lambda, T) = \frac{2\pi c k T}{\lambda^4}$

Bigger T, bigger $\mathcal{I}$

$\lambda = \frac{c}{\nu}$ $\quad \mathcal{I} = \frac{2\pi c k T}{(\frac{c}{\nu})^4}$

2.) Sketch the intensity vs. frequency curves for the same two radiators below:





$3/5 \times 2 = 6/10$

3.) Rank the following in terms of (thermal) DeBroglie wavelength from longest to shortest: (a) An iron atom at room temperature; (b) a helium atom at room temperature; (c) a baseball at room temperature; (d) an electron at 2K; (e) a helium atom at 2K. d, e, b, a, c ✓ 5/5

4.) A certain photocathode is illuminated by a lamp producing 100 kW and yields a current of 3nA and the stopping potential is measured to be -1.4eV. The lamp is replaced with one producing 200 kW at the same (filament) temperature. What are the current and stopping potential now? 6 ✓ nA and ~~-2.8~~ eV.

3/5 −

$P = 100\ kW$ $\quad W = J/s$

$I = 3\ nA$ $\quad A = C/s$

$E = \frac{P}{n}$

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Part II: Problems (20 pts each): Show all work and indicate final answer(s) clearly. You may use scratch paper. Please make sure important steps are shown clearly and logically on clean, numbered sheets with your name on each page.

5.) What is the high-temperature limit, i.e. $E<<kT$, of the Maxwell-Boltzmann probability distribution function, $f(E) = exp\{-E/kT\}$, (to leading order in the energy)?

6.) A He-Ne laser emits red light ($\lambda = 632.8$ nm) with a power of 10^{-3} W.

(a) (15 pts) How many photons per second are being emitted?

(b) (5pts) Assume that all the photons emitted correspond to the case of stimulated emission and further that none of these photons get re-absorbed. You can then use the number of photons emitted to make an estimate of the number of atoms of Ne that are excited by collisions with pumped-up He atoms. How many Ne atoms (approximately) are excited at any one time in the cavity? *(Hint: how many photons are emitted per atom in this type of atomic process?)*

7.) The power dissipated by an AC current flowing through a circuit is given by the real part of

$P(t) = V(t)I(t)$. If the voltage is given by $V(t) = V_o exp\{-i\omega t\}$ and the current is given by $I(t)=I_o exp\{-i\omega t\}$, calculate the power in terms of trigonometric functions.

8.) What temperature must a blackbody be such that the wavelength of radiation at the intensity maximum can induce the transition from n=1 to n=2 in the Bohr model of hydrodgen?

BONUS: Use the Maxwell-Boltzmann distribution and the results of problem #6 to obtain an estimate of the operating temperature of the He-Ne laser. Assume that about half the total number of Neon atoms are in the excited state at any one time and only consider the population of the two levels that participate in lasing action **(10pts total, partial credit counts!)**

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#5 $E << KT$ $f(E) = e^{\frac{-E}{KT}}$

20/20

$$\sum_{n=0}^{\infty} \frac{f^{(n)}(x-a)^{(n)}}{n!} \quad @ \quad a=0$$

$f(0) = e^0 = 1$

$f'(E) = \frac{-1}{KT} e^{\frac{-E}{KT}}$

$f'(0) = \frac{-1}{KT} e^0 = \frac{-1}{KT}$

$f''(E) = \left(\frac{1}{KT}\right)^2 e^{\frac{-E}{KT}}$

$f''(0) = \left(\frac{1}{KT}\right)^2 e^0 = \left(\frac{1}{KT}\right)^2$

$f'''(E) = -\left(\frac{1}{KT}\right)^3 e^{\frac{-E}{KT}}$

$f'''(0) = -\left(\frac{1}{KT}\right)^3$

$f^4(E) = \left(\frac{1}{KT}\right)^4 e^{\frac{-E}{KT}}$

$f^4(0) = \left(\frac{1}{KT}\right)^4$

$$\sum_{n=0}^{\infty} \frac{f^{(n)}(x-a)^n}{n!} : 1 + \frac{\left(\frac{-1}{KT}\right)(x)}{1} + \frac{\left(\frac{1}{KT}\right)^2 x^2}{2} + \frac{\left(-\frac{1}{KT}\right)^3 x^3}{6} + \frac{\left(\frac{1}{KT}\right)^4 x^4}{24}$$

$$\sum_{n=0}^{\infty} \frac{f^{(n)}(x-0)^n}{n!} : 1 - \left(\frac{1}{KT}\right)x + \frac{1}{2}\left(\frac{1}{KT}\right)^2 x^2 - \frac{1}{6}\left(\frac{1}{KT}\right)^3 x^3 + \frac{1}{24}\left(\frac{1}{KT}\right)^4 x^4$$

Every term after the first derivative only contributes a small amount. Therefore we can disregard everything after the first derivative

$$\boxed{\sum_{n=0}^{\infty} \frac{f^{(n)}(x-a)^n}{n!} = 1 - \left(\frac{1}{KT}\right)x}$$

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This is what I remember from the book

$\boxed{h = 6.626 \times 10^{-34}\ J \cdot s\ ?}$

#6 $\lambda = 632.8\ nm$ $P = 10^{-3}\ W$

a.) γ / s ?

$E = \frac{P}{n} = h\nu$

$\nu = \frac{c}{\lambda}$

$h = 6.626 \times 10^{-34}\ J \cdot s$

$P = J/s$

$E = h\nu = \frac{hc}{\lambda} = \frac{1240\ eV \cdot nm}{632.8\ nm} = 1.96\ eV$

$1.602 \times 10^{-19}\ J/eV$?

$E = 1.96\ eV$ ✓ $E = \cancel{3.135\ J}$ WHOA LEROY! $\nu = 4.74 \times 10^{4}\ \frac{1}{s}$

$T =$

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$E = J$

$P = \frac{J}{s}$

$n = \frac{1}{s}$

$\therefore\ n = \frac{P}{E} = \frac{J/s}{J} = \frac{1}{s}$ ✓

-1 $n = \frac{P}{E} = \frac{10^{-3}\ W}{3.135\ J} = 3.19 \times 10^{-4}\ \gamma/s$

$\boxed{\# = 3.19 \times 10^{-4}\ \gamma/s}$

$\frac{J/s}{J} = \frac{1}{s}$

b.)

$\nu = \frac{c}{\lambda} = \frac{3.0 \times 10^{8}\ m/s}{632.8 \times 10^{-9}\ m} = 4.74 \times 10^{14}\ \frac{1}{s}$

$T = 2.109 \times 10^{-15}\ s$

$\# = \frac{\gamma}{s} \cdot s = 3.19 \times 10^{-4}\ \frac{\gamma}{s}\ (2.109 \times 10^{-15}\ s) = 6.72 \times 10^{-19}\ \gamma$

$\boxed{\# = 6.72 \times 10^{-19}\ \gamma}$

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I am so lost. I know these numbers make no sense but I have no clue what to do.

DIVIDE BY 2...

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#7 $\quad P(t) = V(t)\, I(t) \qquad e^{-i\omega t} = \cos(\omega t) - i\sin(\omega t)$

$$V(t) = V_0 e^{-i\omega t} = V_0(\cos(\omega t) - i\sin(\omega t)) \quad (1)$$

$$I(t) = I_0 e^{-i\omega t} = I_0(\cos(\omega t) - i\sin(\omega t)) \quad (2)$$

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$(1) * (2)$: $\quad V_0(\cos(\omega t) - i\sin(\omega t))(I_0(\cos(\omega t) - i\sin(\omega t)))$

$\quad (V_0\cos(\omega t) - V_0 i\sin(\omega t))(I_0\cos(\omega t) - I_0 i\sin(\omega t)) \quad -1$

[illegible] PROOF THIS

$\quad V_0I_0\cos^2(\omega t) - 2V_0I_0 i\sin(\omega t)\cos(\omega t) + V_0I_0\sin^2(\omega t)$

$-$

$$P = V_0I_0(\cos^2(\omega t) + \sin^2(\omega t) - 2i\sin(\omega t)\cos(\omega t))$$

$(-)(-)(i^2) = -1$

$$P = V_0I_0(-2i\sin(\omega t)\cos(\omega t))$$

$$\boxed{P = -V_0I_0(2i\sin(\omega t)\cos(\omega t))}$$

I know $(2\sin(x)\cos(x))$ simplifies to a different term I just cant remember right now

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$$\frac{1}{\lambda} = R\left(\frac{1}{n_l^2} - \frac{1}{n_u^2}\right) \qquad n_l = 1 \quad n_u = 2$$

$$\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = R\left(1 - \frac{1}{4}\right) = \frac{3}{4}R \qquad R = 1.1\times10^7\,m^{-1}$$

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$$\frac{1}{\lambda} = \frac{3}{4}R = \frac{3}{4}(1.1\times10^7\,m^{-1}) = 8.25\times10^6\,m^{-1}$$

$$\frac{1}{\lambda} = 8.25\times10^6\,m^{-1} \qquad \lambda = 121.2\ nm \qquad \lambda_{max} = 121.2\times10^{-9}\,m$$

$$\lambda_{max}T = 2.898\times10^{-3}\,m\cdot K$$

$$T = \frac{2.898\times10^{-3}\,m\cdot k}{\lambda_{max}} = \frac{2.898\times10^{-3}\,m\cdot K}{121.2\times10^{-9}\,m} = 23{,}910.9\ K$$

$$\boxed{T = 23{,}911\ K}$$